

1 CLAIMS

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3 What is claimed is:

1 1. A method for performing concurrent mark-sweep garbage collection,
2 comprising:
3 receiving an application;
4 executing the application in at least one thread;
5 determining if available space in a heap falls below a threshold;
6 performing mark-sweep garbage collection, concurrently while executing
7 the application, in a heap block of the heap using a first bit vector, a second bit
8 vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap
9 block, if the available space falls below the threshold; and otherwise,
10 continuing executing the application and monitoring if the available space
11 in the heap falls below the threshold, until the execution of the application is
12 complete.

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1 2. The method of claim 1, wherein the heap comprises at least one heap
2 block.

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1 3. The method of claim 1, further comprising initializing a concurrent
2 mark-sweep garbage collector.

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1 4. The method of claim 3, wherein initializing the concurrent mark-sweep
2 garbage collector comprises setting each bit in the first bit vector and the second
3 bit vector to 0, and pointing the mark bit vector pointer to the first bit vector and
4 the sweep bit vector pointer to the second bit vector.

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1 5. The method of claim 1, wherein performing mark-sweep garbage
2 collection comprises:
3 invoking at least one garbage collection thread to trace live objects in the
4 heap block concurrently while executing the application; and

5 reclaiming storage space occupied by objects other than the live objects
6 in the block concurrently while tracing the live objects in the block and executing
7 the application.

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1 6. The method of claim 5, wherein tracing the live objects in the heap
2 block comprises parallel marking the live objects by at least one garbage
3 collection thread.

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1 7. The method of claim 6, wherein parallel marking the live objects
2 comprises setting bits corresponding to starting addresses of the live objects in a
3 bit vector pointed to by the mark bit vector pointer to 1, by the at least one
4 garbage collection thread.

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1 8. The method of claim 5, wherein reclaiming the storage space occupied
2 by objects other than the live objects in the heap block comprises sweeping the
3 heap block to make the said storage space allocable by using a bit vector
4 pointed to by the sweep bit vector pointer.

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1 9. The method of claim 6, further comprising toggling a bit vector pointed
2 to by the mark bit vector pointer with a bit vector pointed to by the sweep bit
3 vector pointer after marking the live objects in the heap block is complete.

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1 10. The method of claim 8, further comprising setting the bit vector back
2 to 0 after completing sweeping the heap block.

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1 11. The method of claim 1, further comprising performing another cycle of
2 concurrent mark-sweep garbage collection when available space in the heap
3 falls below the threshold again.

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1 12. A method for automatically collecting garbage objects, comprising:
2 receiving a first code;

3 compiling the first code into a second code;
4 executing the second code in at least one thread; and
5 automatically performing mark-sweep garbage collection using bit vector
6 toggling, concurrently with the executing second code, to ensure there is storage
7 space available for executing the second code.

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1 13. The method of claim 12, wherein automatically performing mark-
2 sweep garbage collection using bit vector toggling comprises detecting if
3 available space in a heap falls below a threshold and invoking the concurrent
4 mark-sweep garbage collection when the available space falls below the
5 threshold.

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1 14. The method of claim 13, wherein the heap comprises at least one
2 heap block.

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1 15. The method of claim 13, further comprising using two bit vectors for a
2 heap block, one for marking and the other for sweeping, and toggling the two bit
3 vectors after marking phase for the heap block is complete.

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1 16. A system for concurrent mark-sweep garbage collection, comprising:
2 a root set enumeration mechanism to enumerate references to live
3 objects in a heap;

4 a live object tracing mechanism to parallel trace live objects in a heap
5 block and mark the live objects in a first bit vector pointed to by a mark bit vector
6 pointer in the heap block, concurrently with execution of an application; and

7 a garbage sweeping mechanism to sweep storage space occupied by
8 garbage objects to make the storage space allocable using a second bit vector
9 pointed to by a sweep bit vector pointer in the heap block, concurrently with the
10 execution of the application and live object marking.

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1 17. The system of claim 16, further comprising a bit vector toggling
2 mechanism to toggle the first bit vector pointed to by the mark bit vector pointer
3 and the second bit vector pointed to by the sweep bit vector pointer in the heap
4 block.

1 18. The system of claim 16, wherein the live object tracing mechanism
2 comprises:

3 a live object search mechanism to parallel search live objects in a heap
4 block by at least one garbage collection thread;

5 a live object marking mechanism to parallel mark the live objects in a bit
6 vector stored in the heap block by the at least one garbage collection thread;

7 a live object scanning mechanism to parallel scan any objects reachable
8 from the live objects in the heap; and

9 a conflict prevention mechanism to prevent more than one garbage
10 collection thread from marking the same object.

1 19. A managed runtime system, comprising:

2 a just-in-time compiler to compile an application into a code native to an
3 underlying computing platform;

4 a virtual machine to execute the application; and

5 a garbage collector to trace live objects, mark the live objects in a first bit
6 vector pointed to by a mark bit vector pointer in a heap block of a heap, and
7 toggle the bit first vector pointed to by the mark bit vector pointer with a second
8 bit vector pointed to by a sweep bit vector pointer at the end of marking phase,
9 concurrently with execution of the application.

1 20. The system of claim 19, further comprising a garbage sweeping
2 mechanism to sweep storage space occupied by garbage objects to make the
3 storage space allocable using a bit vector pointed to by the sweep bit vector
4 pointer, concurrently with the execution of the application and live objects
5 marking.

1 21. The system of claim 19, wherein the garbage collector comprises:
2 a live object marking mechanism to parallel mark the live objects in the
3 first bit vector pointed to by the mark bit vector in the heap block of the heap; and
4 a bit vector toggling mechanism to toggle the first bit vector pointed to by
5 the mark bit vector pointer and the second bit vector pointed to by the sweep bit
6 vector pointer.

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1 22. A computer-readable medium having stored thereon a data structure
2 comprising:

3 a first field containing a first pointer pointing to a mark bit vector in a heap
4 block of a heap;

5 a second field containing a second pointer pointing to a sweep bit vector
6 in the heap block;

7 a third field containing a first bit vector representing at least one of
8 marking and sweeping statuses of objects stored in the heap block; and

9 a fourth field containing a second bit vector representing at least one of
10 marking and sweeping statuses of objects stored in the heap block.

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1 23. The computer-readable medium of claim 22, wherein the data
2 structure is stored in a header area of the heap block of the heap.

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1 24. The computer-readable medium of claim 22, wherein the first pointer
2 is initially pointed to the first bit vector and the second pointer is initially pointed
3 to the second bit vector, when garbage collector is initialized; and the first bit
4 vector and the second bit vector are toggled after the heap block is marked.

1 25. An article comprising: a machine accessible medium having content
2 stored thereon, wherein when the content is accessed by a processor, the
3 content provides for performing concurrent mark-sweep garbage collection by:
4 receiving an application;
5 executing the application in at least one thread;

6 determining if available space in a heap falls below a threshold;
7 performing mark-sweep garbage collection, concurrently while executing
8 the application, in a heap block of the heap using a first bit vector, a second bit
9 vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap
10 block, if the available space falls below the threshold; and otherwise,
11 continuing executing the application and monitoring if the available space
12 in the heap falls below the threshold, until the execution of the application is
13 complete.

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1 26. The article of claim 25, wherein the heap comprises at least one heap
2 block.

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1 27. The article of claim 25, further comprising content for initializing a
2 concurrent mark-sweep garbage collector.

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1 28. The article of claim 27, wherein content for initializing the concurrent
2 mark-sweep garbage collector comprises content for setting each bit in the first
3 bit vector and the second bit vector to 0, and pointing the mark bit vector pointer
4 to the first bit vector and the sweep bit vector pointer to the second bit vector.

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1 29. The article of claim 25, wherein content for performing mark-sweep
2 garbage collection comprises content for:
3 invoking at least one garbage collection thread to trace live objects in the
4 heap block concurrently while executing the application; and
5 reclaiming storage space occupied by objects other than the live objects
6 in the block concurrently while tracing the live objects in the block and executing
7 the application.

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1 30. The article of claim 29, wherein content for tracing the live objects in
2 the heap block comprises content for parallel marking the live objects by at least
3 one garbage collection thread.

1 31. The article of claim 30, wherein content parallel marking the live
2 objects comprises content for setting bits corresponding to starting addresses of
3 the live objects in a bit vector pointed to by the mark bit vector pointer to 1, by
4 the at least one garbage collection thread.

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1 32. The article of claim 29, wherein content for reclaiming the storage
2 space occupied by objects other than the live objects in the heap block
3 comprises content sweeping the heap block to make the said storage space
4 allocable by using a bit vector pointed to by the sweep bit vector pointer.

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1 33. The article of claim 30, further comprising content for toggling a bit
2 vector pointed to by the mark bit vector pointer with a bit vector pointed to by the
3 sweep bit vector pointer after marking the live objects in the heap block is
4 complete.

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1 34. The article of claim 32, further comprising content for setting the bit
2 vector back to 0 after completing sweeping the heap block.

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1 35. The article of claim 25, further comprising content performing another
2 cycle of concurrent mark-sweep garbage collection when available space in the
3 heap falls below the threshold again.

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1 36. An article comprising: a machine accessible medium having content
2 stored thereon, wherein when the content is accessed by a processor, the
3 content provides for automatically collecting garbage objects by:
4 receiving a first code;
5 compiling the first code into a second code;
6 executing the second code in at least one thread; and
7 automatically performing mark-sweep garbage collection using bit vector
8 toggling, concurrently with the executing second code, to ensure there is storage
9 space available for executing the second code.

1 37. The article of claim 36, wherein content for automatically performing
2 mark-sweep garbage collection using bit vector toggling comprises content for
3 detecting if available space in a heap falls below a threshold and invoking the
4 concurrent mark-sweep garbage collection when the available space falls below
5 the threshold.

1 38. The article of claim 37, wherein the heap comprises at least one heap
2 block.

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1 39. The article of claim 37, further comprising content for using two bit
2 vectors for a heap block, one for marking and the other for sweeping, and
3 toggling the two bit vectors after marking phase for the heap block is complete.